DEVELOPMENT OF PRE-CRASH SAFETY SYSTEM

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ABSTRACT

A large number of means for active safety and passive safety have been studied for road traffic safety, and various safety systems have been commercialized. It has now become important to link active safety with passive safety to enhance overall safety. Therefore, a pre-crash safety system has been developed that helps to reduce crash injuries by determining the likelihood of a crash in advance, and activating active safety systems and passive safety systems at an earlier stage.

This paper describes the configuration, functions, and effects of this pre-crash safety system. The newly developed system consists of a pre-crash sensor, a pre-crash seat belt, and pre-crash brake assist. The pre-crash sensor is composed of a millimeter-wave radar that detects forward obstacles and a pre-crash safety computer that helps to determine in advance whether a crash is unavoidable, based on location, speed and course of an obstacle. The pre-crash seat belt, which employs a mechanism to retract the seat belt by a motor, helps to reduce crash injuries through earlier restraint of front occupants. The pre-crash brake assist helps to reduce the crash speed by quickly generating a large brake force in response to the driver's brake pedal operation even when sudden braking is not being performed.

1. INTRODUCTION

In recent years, vehicle safety technologies have advanced. Development has been actively conducted regarding passive safety technologies, for example, body structure optimization, occupant protection systems such as front dual-stage airbags and side curtain shield airbags, vehicle compatibility, and pedestrian protection, as well as regarding active safety technologies like brake assist, vehicle dynamics control such as VSC(*Vehicle Stability Control), and visibility support such as night view and AFS(*Adaptive Front-light System).

Analysis results of traffic accidents in Japan show that approximately 70% of fatal and serious injury accidents are caused by delayed driver awareness, such as the driver paying insufficient attention to the road ahead, and inadequate safety precautions. Insufficient attention to the road ahead and inadequate safety precautions account for as much as 54% of frontal crashes. (Figure1) [1]

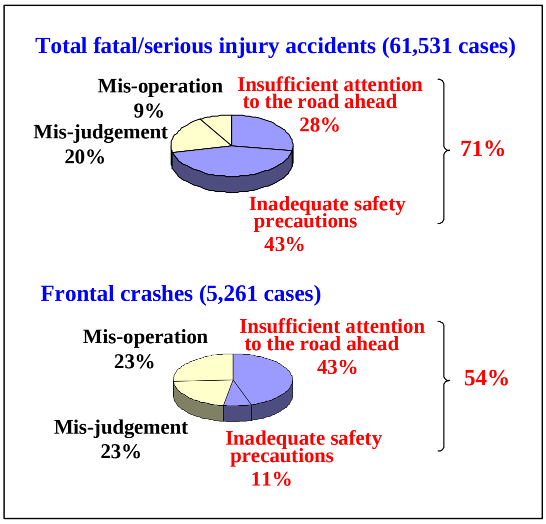

Figure1; Cause analysis of fatal and serious injury accident in Japan

Furthermore, traffic accident analysis results also indicate cases where no accident-avoiding maneuvers, such as braking and steering, are performed at the time of accident account for approximately 40% of frontal crashes. (Figure2)[1]

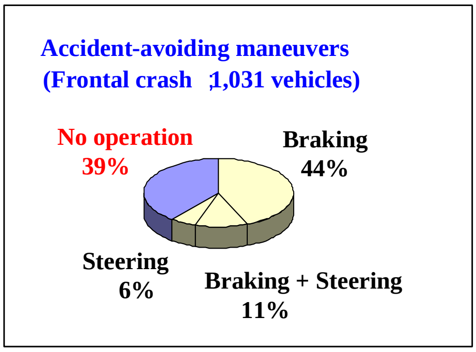

Figure2; Analysis of accident avoiding maneuvers

Therefore, a driver assist system which applies monitoring technologies such as radar may help in reducing the number of traffic accidents and crash injuries. A pre-crash safety system has been developed which functions when an object is detected by radar and a crash is determined to be unavoidable, as well as when an emergency maneuvers is performed by the driver. The development of this pre-crash safety system has enabled active safety and passive safety to be combined. (Figure3)

Figure3; Conbination of active safety and passive safety

This paper introduces the configuration, functions, and effects of the developed pre-crash safety system, and also explores the possible future developments of the system.

2. SYSTEM CONFIGURATION

The configuration of the developed vehicle system is illustrated in Figure4. The system mainly consists of the following: a pre-crash sensor that consists of a millimeter-wave radar and a pre-crash safety computer (hereinafter called the "PCS computer"), pre-crash seat belts and a pre-crash brake assist that consists of a brake control computer and a brake actuator.

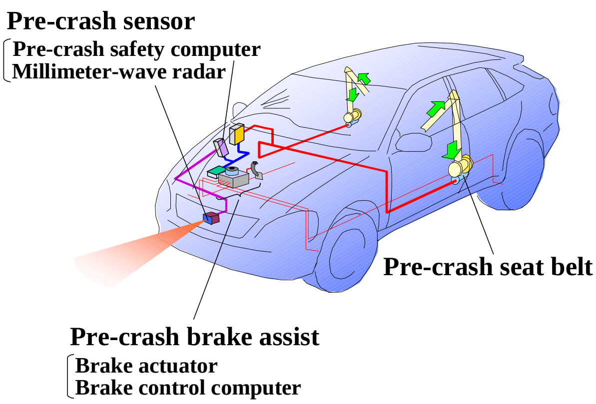

Figure4; Configuration of the developed "Pre-crash safety system"

The pre-crash sensor recognizes an obstacle ahead of the vehicle and helps to determine in advance whether a crash is unavoidable, based on location, speed, and course. After an unavoidable crash is determined, the pre-crash seat belt is retracted before the crash occurs using a seat belt motor, so as to restrain front occupants at an earlier stage, thereby enhancing occupant protection performance. The pre-crash brake assist operates after an unavoidable crash is determined, applying additional hydraulic pressure in response to the brake pedal depression force, so as to achieve enhanced braking performance. The operating trigger of each system is shown in Figure5.

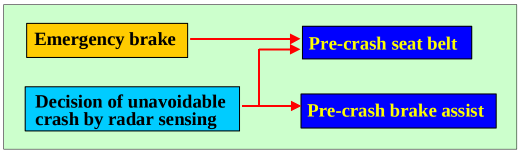

Figure5; System operation trigger of the developed vehicle system

3. MAJOR COMPONENT

3.1 PRE-CRASH SENSOR

The pre-crash sensor comprises the millimeter-wave radar for detecting obstacles ahead, the PCS computer for predicting crashes on the basis of the information from the millimeter-wave radar, and various sensors, including a vehicle speed sensor. (Figure6)

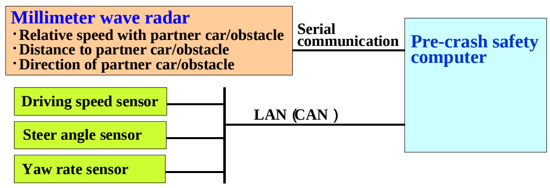

Figure6; Various sensors that consists the pre-crash sensor

An electronic scanning system was adopted for the millimeter-wave radar for detecting obstacles, so as to obtain more accurate sensing over a broad range.

The millimeter-wave radar primarily consists of an antenna for transmitting and receiving electric waves, a millimeter-wave module, and a CPU board that processes obstacle information. The millimeter-wave radar detects the distance, relative speed, and direction with respect to an obstacle within the detection area.

Overviews of the millimeter-wave radar and its internal structure are shown in Figures.7 and 8, respectively.

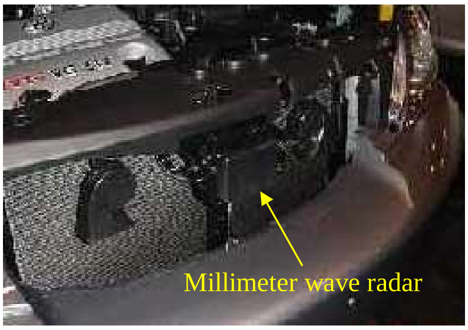

Figure7; Millimeter wave radar in the car

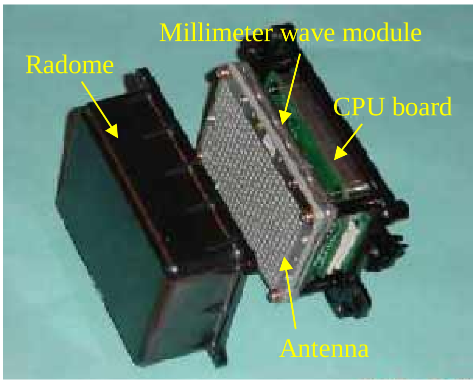

Figure8; Internal structure of the millimeter wave radar

Table 1 shows the basic specifications of the millimeter-wave radar.

Item	Specification
System	Electronic beam scanning
Oscillation frequency	76GHz
Detection distance	Approx.150m
Detection range	Approx.20deg lateral
Detectable measurements	Distance, relative speed, direction

Table1; Specification of the millimeter wave radar

The PCS computer, which consists of a housing, a CPU board and other elements, predicts a course of an object based on information such as the distance to the object, the relative speed and direction of the object as detected by the millimeter-wave radar, and combines the predicted results with information such as host-vehicle speed and course to determine whether a crash is unavoidable. An outline of the logic is described in Figure9.

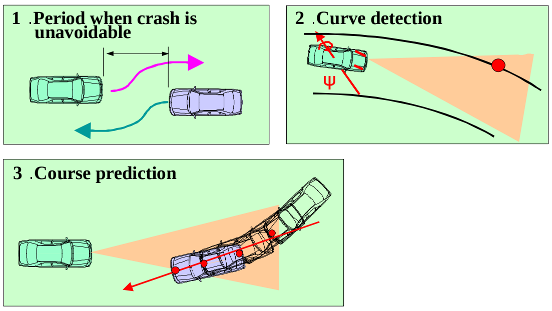

Figure9; Outline of the crash prediction logic

3.2 PRE-CRASH SEAT BELT

A pre-crash seat belt mechanism (electric motor, reduction gear, clutch mechanism, etc.) for retracting the seat belt has been added to a conventional seat belt retractor (pretensioner + force limiter mechanism). Since the seat belt retractor is disconnected from the reduction gear and the electric motor by the clutch mechanism, there are no effects on pulling out or retracting the seat belt under typical use.

In addition, because the pre-crash seat belt is operated by an electric motor, it can be used repeatedly. Figure10 is a photograph showing an overview of the pre-crash seat belt, and Figure11 is a schematic drawing of the pre-crash seat belt mechanism.

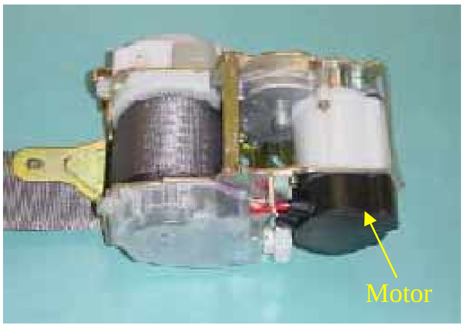

Figure10; Pre-crash seat belt

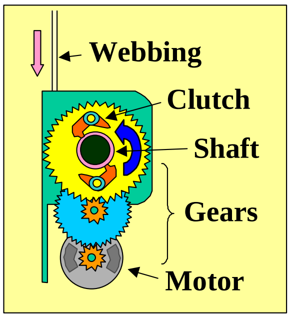

Figure11; Schematic drawing of the pre-crash seat belt mechanism

Figure11 shows that the seat belt is retracted by rotation of the shaft in the direction indicated by the arrow. However, the seat belt retractor is normally disconnected from the motor by the clutch mechanism. When an unavoidable crash is determined, a current is supplied to the motor, which rotates in the direction indicated by the arrow, activating the clutch mechanism and retracting the seat belt.

To release the seat belt retraction, the motor is rotated in reverse to disengage the clutch mechanism. Once the clutch mechanism is disengaged, the shaft becomes free, returning the seat belt to its original state.

The pre-crash seat belt is activated in two situations: when an unavoidable crash is determined by the pre-crash sensor; and when an emergency brake operation is executed by the driver. The seat belt automatically returns to its original state once the crash is avoided. (Figure12)

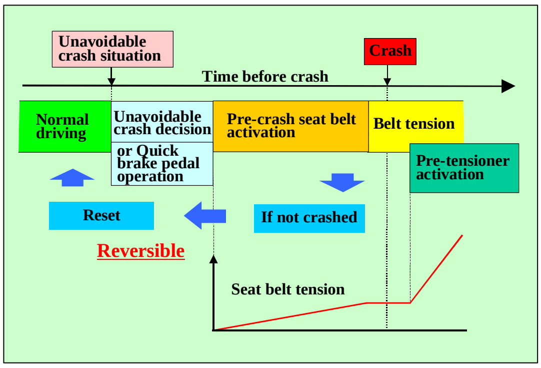

Figure12; Activation of the pre-crash seat belt

3.3 PRE-CRASH BRAKE ASSIST

Systems already exist that enhance braking force by using a brake booster and pump pressurization when a driver's brake pedal operation is detected and a large braking force is judged to be required. This type of system is called brake assist and is installed in some vehicles on the market.

The pre-crash brake assist differs from these systems in that activation judgement is based on the crash prediction by the pre-crash sensor. Since the pre-crash brake assist is expected to operate promptly upon encountering an obstacle ahead, it will help to bee effective in reducing injuries caused by crash accidents with these obstacles.

The brake actuator used in the pre-crash brake assist has various functions related to brake control, such as VSC, ABS, and the traction control function, and is integrally constructed with a brake control computer, thereby allowing installation in vehicles. Figure13 shows the brake actuator.

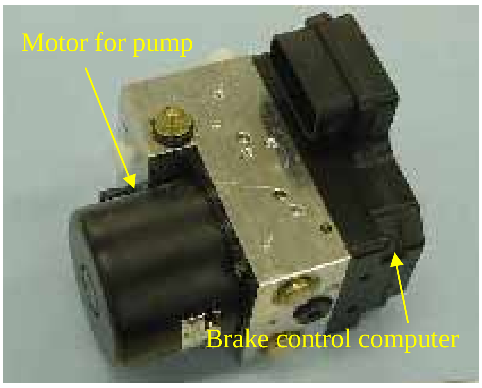

Figure13; Brake actuator

A trochoid gear pump is used as a built-in pump, enabling lower hydraulic pulsation, and quiet and smooth pressurization. The hydraulic pressure generated by the pump is regulated by a linear differential-pressure valve, which is capable of changing the relief pressure based on a electric current value, and is able to enhance the hydraulic pressure generated by the driver's brake pedal operation. In addition, a hydraulic pressure sensor is incorporated so as to detect the hydraulic pressure generated by the driver's brake pedal operation.

Upon receiving an unavoidable crash decision signal from the PCS computer, the pump motor is started immediately and the hydraulic pressure generated by the driver's brake pedal operation is detected. A current in response to the detected hydraulic pressure is then supplied to the linear differential-pressure valve so as to carry out pressurization assist.

The hydraulic pressure introduced into the wheel cylinders through this pressurization is about twice that under normal conditions. Thus, even if the driver changes the force of brake pedal depression after the operation of the pre-crash brake assist, the hydraulic pressure is adjusted proportionally. The purpose of such hydraulic pressure regulation is to prevent unconditional generation of high pressure, and to generate sufficient braking force while allowing control by the driver. Therefore, the pressurization control is not executed without the driver's operation of the brake pedal.

4. PREDICTION OF SYSTEM EFFECTS

4.1 PRE-CRASH SEAT BELT

The pre-crash seat belt helps to reduce the forward movement of front passengers by retracting the seat belt prior to a crash in order to enhance the initial restraint of occupants when the crash occurs. A test that corresponded to 55km/h head on fixed barrier impact was conducted on the assumption that occupants wore seat belt in condition of typical use. The chest displacement of occupant was measured and compared with a case in which the pre-crash seat belt was not added. A difference of chest displacement thus obtained is shown in Figure14.

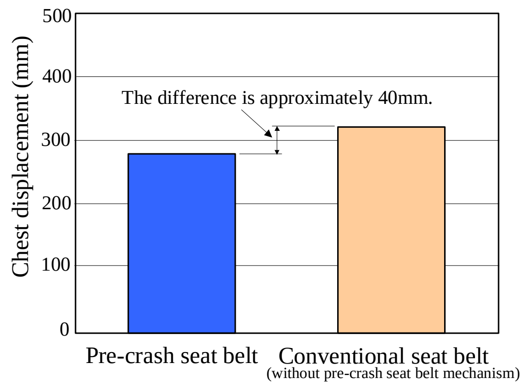

Figure14; Chest displacement reduction effect by the pre-crash seat belt (Correspond to 55km/h head on fixed barrier impact)

The test results indicate that a displacement reduction effect of approximately 40mm can be achieved.

4.2 PRE-CRASH BRAKE ASSIST

A test was conducted on the assumption that the driver recognized an obstacle ahead while driving at 50 km/h and applied the brake 0.8 seconds prior to the crash. In consideration of individual differences, three conditions from 50 to 150 N were used as the driver's braking force, and three conditions from high speed to low speed were used for the brake operation speed. The vehicle speed at the time of the crash was measured and compared with a case in which the system was not operated. A vehicle speed difference thus obtained is shown in Figure15 as the speed reduction effect.

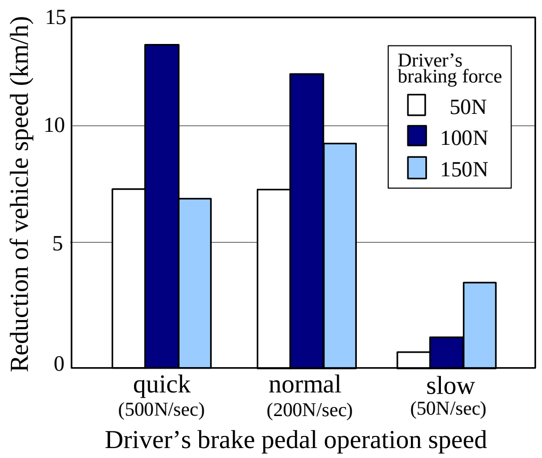

Figure15; Speed reduction effect by the pre-crash brake assist (Driving at 50km/h and applied the brake 0.8 seconds prior to the crash)

The vehicle speed reduction effect is typically greater when the brake operation speed is approximately between the high and medium levels. The test results indicate that a speed reduction effect of 10 km/h or higher can be achieved particularly when the braking force is 100 N.

5. PROSPECT FOR THE FUTURE

In the future, monitoring technology, which is a key technology to the pre-crash safety system will combine radar information with image information and the like, and it is thought that it will enable identification of obstacles and more discerning accident prediction.

Furthermore, a vehicle safety system which applies monitoring technology could perhaps be expanded one day to an autonomous driving support, as represented by the forward obstacle collision prevention support system, and further to network-based driving support that includes infrastructure coordination and vehicle-to-vehicle communication.

6. CONCLUSION

A pre-crash safety system where the radar for monitoring technology is applied has been described. In the future, this technology may be applied to side impacts, rear impacts, and other types of accidents in addition to frontal impacts. Thus, greater expectations will be placed on the pre-crash safety system as a technology to help reduce traffic accidents and crash injuries. It is also desired that the development of many technologies are promoted to provide contributions to society.

In closing, we would like to express our sincere gratitude to Denso Corporation, Advics Co.,LTD. and Tokai Rika Co.,LTD. for their cooperation in developing the pre-crash sensor, the pre-crash seat belt and the pre-crash brake assist, respectively.

REFERENCES

[1] ITARDA report 2001(Japan)